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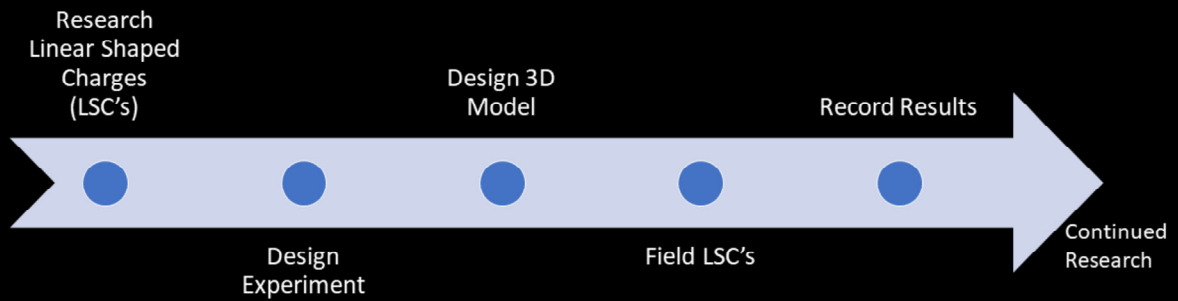|	
Title:	3D Printed Linear Shaped Charges
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3D Printed Linear Shaped Charges

Presented By: Alex Tafoya

Here I will give a brief overview of the series of events to take place for the research project.

LSC Research

- Optimal Mass of liner/Mass of Explosive (M/C) Ratio: (1.4) Copper liner.

- Explosive material: Semtex

- 3D Printed charges M/C: (.25)
  (1lb copper liner / 4lb charge)

- Explosive material: Comp C4 (91% RDX 9% Plasticizer)

1. V. Bohanek, M. Dobrilović, V. Škrlec //Technical Gazette 21, 3(2014), p.(525-531)

The optimal mass ratio from the referenced paper was achieved by using Semtex explosive. We used C4 due to its low cost. We also scaled down the angle of the liner to about 53 degrees in order to have a smaller print design.

Design Experiment

Target: Armored Steel (Hardened)

Shot #	Standoff (SO)	Explosive Height (EH)	Liner Angle	Explosive Type	Amount of Explosive	Housing Type
1	1"	0.5"	100	C4	3lbs	Steel
2	None	1.8"	53 deg	C4	4lbs	Tough PLA
3	1.8"	1.8"	53 deg	C4	3lbs	Tough PLA
4	1.8"	1.8"	53 deg	C4	4lbs	Tough PLA
5	2.4"	1.8"	53 deg	C4	4lbs	Tough PLA
*6	1"	0.5"	100 deg	C4	3lbs	Steel
*7	1"	1.8"	53 deg	C4	4lbs	Tough PLA
*8	None	1.8"	53 deg	C4	4lbs	Tough PLA
*9	1"	2.4"	53 deg	C4	6lbs	Tough PLA
*10	None	2.4"	53 deg	C4	6lbs	Tough PLA

*second series pending

The target is a plate of Armored steel that we had laying around. Thickness varies from 4" to 6".

The experiment was broken down into series of shots. The first series was made to gather a baseline of the effectiveness of the 3D printed housings.

The control was the manufactured linear shaped charge housing (Shot 1).

The second series was established after analyzing the results of the first series. It was determined that the higher standoff was not effective.

Second series was executed but the charges were packed by personnel in training and did not yield any results. The second series will be executed again in the future.

Design 3D Model

• Software: Blender

• Goals (per unit):
  • Print time <10 hours
 • Materials used <375g

Initial Design
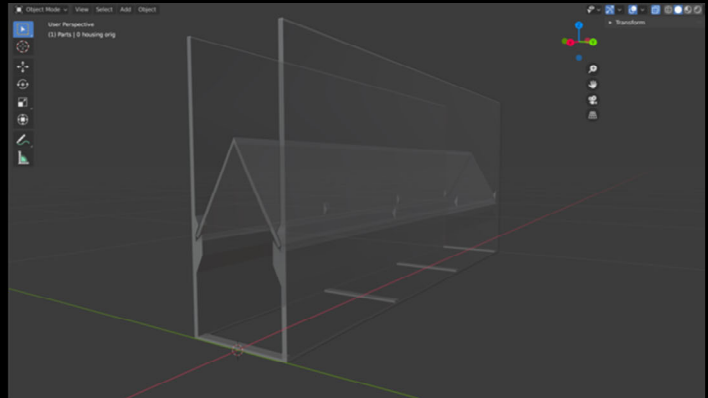
0.8mm nozzle: 7hr 20min @ 306g

Originally a "channel" design (differing from the design of the previously researched article, where Semtex was molded onto the liner alone) in order to achieve high density.

The goals set were to facilitate the ability to print enough housings for a shot that had 1-2 days notice of needing to be executed. Essentially, we wanted something that we could make relatively quickly.
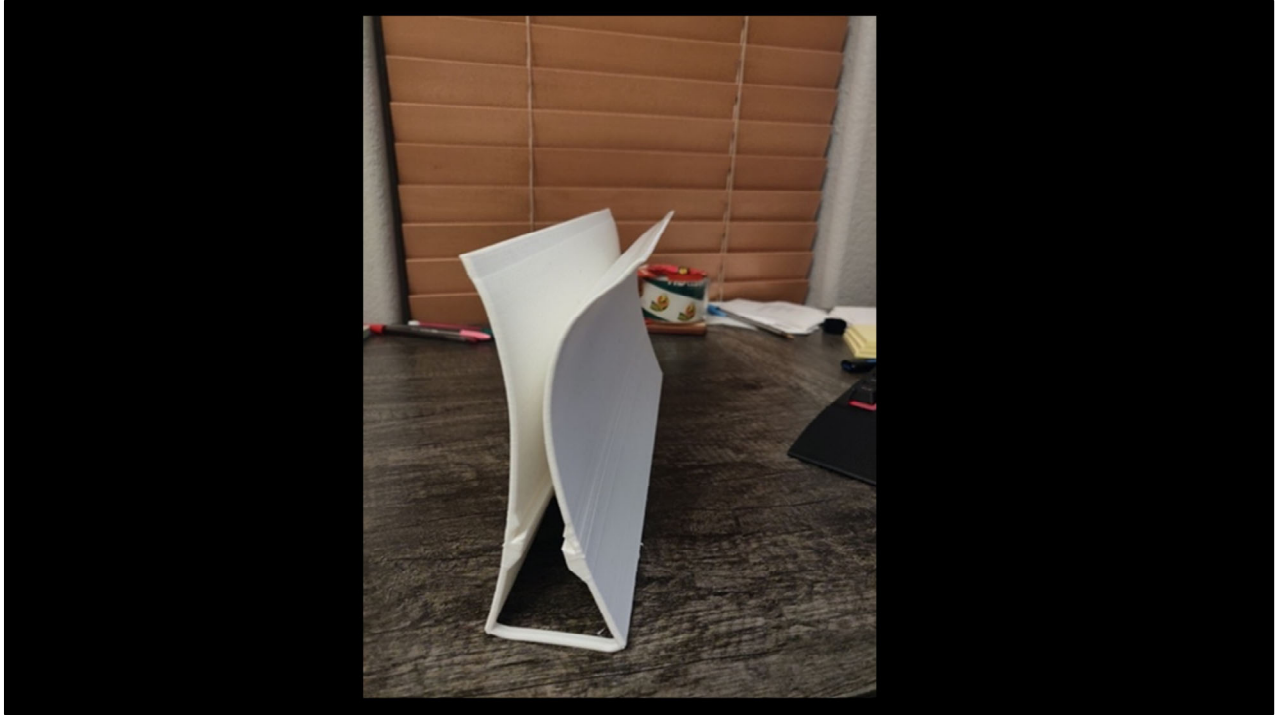
This is the final result of the first print. The material warped due to the high print height and the material for the walls was poorly supported. This was the smallest height that we wanted to test and it was decided that a new design was needed.

Version 4

0.8 nozzle: 6hr 27min @280g
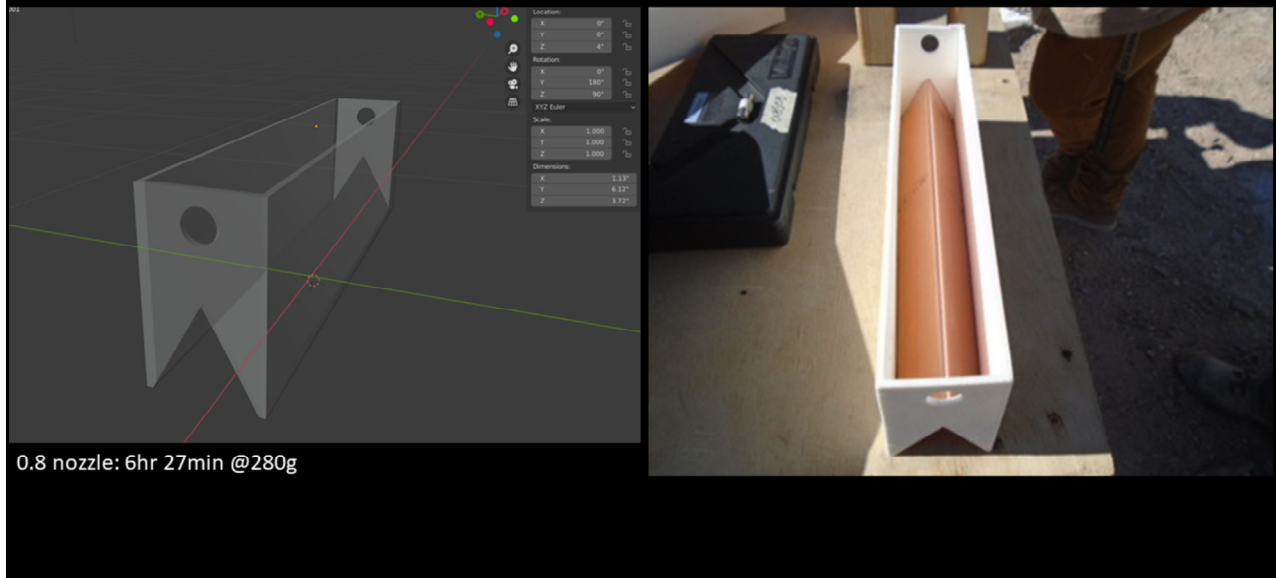
Final design. The walls were closed in and were only slightly thicker to act as a support. The hole on both ends is left for an area to prime into with a detonator.

Field Linear Shaped Charges

Wooden 2x4's were used to assist with packing the material densely as the sides of the housings had a tendency to bow. A similar issue was observed with the steel manufactured housing. C4 was packed densely by tamping small amounts at a time.

Field Linear Shaped Charges

Shot #	Standoff (SO)	Explosive Height (EH)	Liner Angle	Explosive Type	Amount of Explosive	Housing Type
1	1"	0.5"	100	C4	3lbs	Steel
2	None	1.8"	53 deg	C4	4lbs	Tough PLA
3	1.8"	1.8"	53 deg	C4	3lbs	Tough PLA
4	1.8"	1.8"	53 deg	C4	4lbs	Tough PLA
5	2.4"	1.8"	53 deg	C4	4lbs	Tough PLA

The first series of shots in order from left to right. I will identify each charge with the represented information in the chart. Shot 3 was packed less dense than the other shots in the series.

Record Results
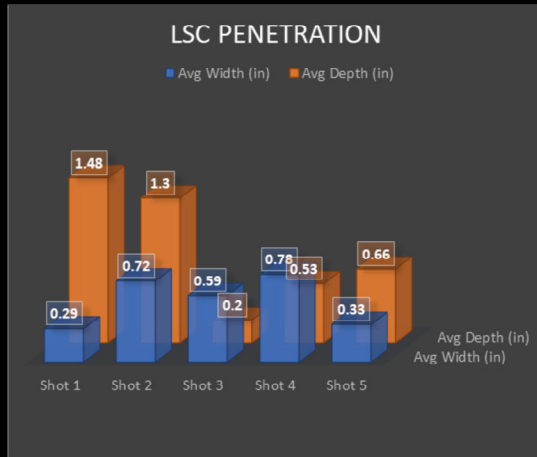
These are the results of the charges. The manufactured housing performed the best with the 3D printed housing closely following.
 Shot 3 performed poorly due to its low density.
It was determined that Shots 4 and 5 performed poorly due to their excessive standoff.

Cost Comparison

Manufactured LSC
- Cost: $178 - $261 / ft
- Composition: RDX

3D Printed LSC
- Cost: $91.42 / ft
  - C4: $60
  - Copper: $12.77
  - Tough PLA: $18.65

*prices quoted before taxes and shipping.

The range of cost shown is the range quoted from all of the different manufactured shaped charges (including the steel housing) that we commonly use.
Our cost for fielding the 3D printed housings is significantly lower.

Summary

- 3D printed housings are effective when packed dense.
- Little to no standoff necessary.
- Significant lower cost.
- Future testing still required.

Questions?